Representations of Health Concepts: A Cognitive Perspective

Jiajie Zhang
Department of Health Informatics
University of Texas Houston Health Science Center

Abstract

This paper discusses the differences between controlled medical vocabularies that are designed as external artifacts and the mental concepts that are inside users' heads and used by users for reasoning, diagnosis, and treatment. It argues that if the controlled vocabularies currently being developed for Electronic Medical Records are to be used by people at all, they should be designed with systematical considerations of the cognitive structures and processes of the users. Without such considerations, the designed vocabularies may not be usable by people, although they may or may be appropriate for machine processing.

Introduction

Electronic medical records (EMR) have the potential to make a highly significant contribution to the advancement of medicine and to the improvement of the quality of healthcare. An ideal EMR would provide complete, accurate, and timely data, alerts, reminders, clinical decision supports, medical knowledge, communications, and other aids at all points of care for all healthcare professionals at all times in a way the quality of healthcare can be dramatically improved. In order to achieve these promised functions of EMR, one necessary condition is a medical vocabulary in structured formats. Many classification systems have been proposed and implemented. However, no existing system at the present time can capture the full scope of medical knowledge. To address the potential problems in the rapid growth of vocabulary contents, Cimino (1997) proposed a set of desiderata for the next generation of standard, reusable, multipurpose controlled vocabularies. On the foundation side, Chute and colleagues (1996) argued that if we want to achieve reliable outcomes and efficient assessment of data, we need to pay significant attention to the basic science of representing what we do to patients. Along this line, Vimla and colleagues (1997) have examined the cognitive issues of how users understand, navigate, and communicate medical knowledge.

This paper examines the representational issues of health concepts from a cognitive perspective. It starts with a definition of representations. Based on this definition, the differences between two types of concepts and vocabularies are described. Then five cognitive theories of concepts and their implications for the representations of health concepts are discussed. Finally, the implications of basic-level concepts and expert-novice differences in concept representations are discussed.

Representations

A representation is something that stands for something else. It is a mapping between a represented world (that which is to be represented) and a representing world (that which does the representing). A representation must specify which aspects (objects and relations) of the represented world are to be modeled in the representing world, as well as how the representing world carries out this mapping (Rumelhart & Norman, 1984).

Figure 1 shows the relations between represented and representing worlds. The represented world is the world of all medical entities, objects, phenomena, events, procedures, etc. They are the things to be represented. The representing world can be the vocabularies invented by designers of classification systems. In this case, the things in the representing world are external to the human mind. They are artifacts created by human beings to carve up and categorize the medical domain in a systematical way. The representing world can also be the mental concepts in the minds of users. In this case, the things in the representing world are internal to the mind. They are the concepts acquired by users through learning and memorization, and they are the concepts that users use to perform diagnoses, reasoning, problem solving, treatment, and so on. The external representations of vocabularies and the internal representations of mental concepts have different properties that may affect the processing of information in a non-trivial way (Zhang & Norman, 1994; Zhang, 1997).

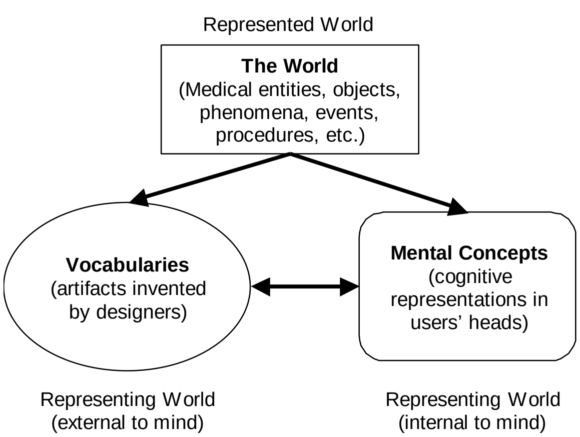

Figure 1. The relations between represented and representing worlds.

The critical issue is the relation between the two representing worlds: vocabularies in external classification systems and mental concepts inside the head of users and used by users (see also Patel & Kushniruk, 1997; Norman, 1988). Let us consider the following possible cases.

In the first case, external vocabularies in classification systems are identical to the internal mental concepts in users' minds, and the external vocabularies are copied from the internal mental concepts. In this case, the regularities of external vocabularies reflect the structures and constraints of mental representations. Therefore, the vocabularies are appropriate for human processing but unlikely to be appropriate for machine processing (e.g., in EMR).

In the second case, the external vocabularies are identical to the internal mental concepts, but the internal mental concepts are copied from the external vocabularies. In this case, the regularities of internal mental concepts reflect the structures and constraints of external vocabularies. The external vocabularies may be appropriate for machine processing. However, it is not likely that they are also appropriate for human processing, unless structures of the human mind are systematically considered during the design of the vocabularies.

In the third case, the external vocabularies are different from the internal mental concepts, and they have evolved independently. In this case, if the external vocabularies are designed to optimize machine processing and the internal mental concepts have evolved to optimize mental processing, the success of the two combined systems will depend on whether there is an efficient translation mechanism between the external vocabularies and the internal mental concepts. If such a mechanism does not exist, it would be very difficult for machines to process human mental concepts and for human beings to process machine vocabularies, as in the case of natural languages vs. programming languages.

In the fourth case, the external vocabularies overlap with the internal mental concepts, and they have evolved interactively. This is a realistic situation and it more or less reflects the status of current classification systems. For example, users acquire mental concepts through internalization of external vocabularies (e.g., through textbooks or handbooks), which in turn might be designed with some consideration of the cognitive properties of the mind. The problem with this situation is that the external vocabularies and the internal mental concepts are neither optimized for machines nor for human minds.

In the design of classification systems of medical vocabularies, we need to be careful about the systems structures. It has been shown that there is a strong cognitive phenomenon called representational determinism (Zhang & Norman, 1995; Zhang, 1997), which says that the format and structure of a representation can guide, constrain, and to some extent determine the way the mind functions. If the structure of a classification system matches the user's cognitive properties, it can enhance the performance of the user. But if there is a mismatch, the user's performance could be greatly hindered.

Mental Concepts

Mental concepts are important components of human intelligence. A mental concept is the mental representation of a category, which is a set of entities. The process of forming a mental concept is called categorization. Without categorization, understanding, prediction, and intelligent behaviors are impossible. In particular, concepts have the following functions. First, concepts provide classifications, that is, we can decide whether an instance belongs to a concept. Second, concepts provide understanding and explanation. Once we know that an instance belongs to a concept, we will know the properties of the instance. For example, once we know that an object is an apple, we know it is edible. Third, concepts support reasoning. Given that Sam is a dog, we can answer questions such as "is Sam a mammal?" and "how many legs does Sam have?" Fourth, concepts provide organizations. Concepts are artifacts that artificially carve the nature into organized chunks. For example, we use limited number of color names to divide the continuous color spectrum. Fifth, concepts support communication. With the same representations of concepts, people are able to communicate with each other and learn indirect experience through communication.

Five Views of Mental Concepts

In the cognitive studies of mental representations of concepts, at least five different views have been proposed (Barsalou & Medin, 1989; Keil 1986; Murphy & Medin, 1985; Rumelhard, Smolensky, McCleland, & Hinton, 1986; Schank, Collins, & Hunter, 1986; Smith & Medin, 1981). The following briefly describes the five views and their corresponding strengths and weaknesses in the explanation of mental concepts.

Classical View. According to the classical view, a concept is defined by a set of necessary and sufficient features. For example, triangle is defined by 3 sides and a sum of 180 degrees for the interior angles. This is a mathematically elegant theory. One good property is that features are nested in subset relations. For example, features of bird are nested in those of Robin because Robin is a subset of bird. Another good property is that a concept is a representation of an entire class, not a set of exemplars. However, this mathematically elegant theory is too restrictive to be a general theory. This view does not allow disjunctive concepts. For example, concept [(f1, f2) or (f3, f4)] has no defining features. And concept [(f1, f2, f3) or (f4, f2, f5)] has no jointly sufficient features. Examples of disjunctive concepts include chair, furniture, game, and many other concepts that are usually described as family resemblance (e.g., Rosch & Mervis, 1975).

Probabilistic view. According to the probabilistic view, features of a concept are salient ones that have a substantial probability of occurring in instances of the concept. If x has some critical sum of weighted features of y, then the x is a y. In addition, the representation of a concept is an abstraction process, not descriptions of features. One important point of this view is the notion of prototypes. A prototype is the best example of a category; it possesses all characteristic features of a category; and it is the central tendency and average of the concept. In this view, a concept is organized around its prototype. This view can easily explain the typicality effect that a more prototypical instance can be processed more efficiently. However, this view cannot easily explain context-dependent concepts. For example, a harmonic is a typical musical instrument in the context of a campfire but not a typical musical instrument in a concert.

Exemplar view. According to the exemplar view, the representation of a concept consists of separate descriptions of some of its exemplars (either instances or subsets). In this view, classification is based on similarity to a particular exemplar. The idea is that a new instance elicits similar old examples and it is assumed that similar instances belong to the same category. For example, you might classify one diagnosis as flu because it reminds you of a case that you know is flu. As another example, the knowledge that large birds are less likely to sing than small birds may be derived from exemplars of small and large birds. The exemplar view is more successful than the probabilistic view, partially because it is more conservative with respect to discarding potentially relevant information. However, it also has problems. For example, it cannot explain how concepts are created in the first place.

Theory-based view. The theory-based view was developed in the studies of how concepts are used in reasoning (e.g., Keil, 1986; Murphy & Medin, 1985; Schank, Collins, & Hunter, 1986). In this view, the organization of concepts is knowledge-based and theory-driven, and categorization is an inference process, not a similarity judgment. For example, "children, money, photo albums, and pets" belong to a concept, which is "things to take out of one's house in case of a fire". In this example, classification is not based on a direct matching of properties of the concept with those in the example, but rather requires that the example have the right explanatory relationship to the theory organizing the concept. One good feature of the theory-based view is that it addresses that question of why we have the concepts we have. In addition, it provides a natural way in which concepts may change, that is, through the addition of new knowledge and theoretical principles.

Connectionist view. According to the connectionist view, concepts are not represented in discrete, localist units such as features and instances. Rather, concepts are represented as activation patterns in parallel and distributed networks of neuron-like units that connect to each other and excite or inhibit each other through dynamic processes (e.g., Rumelhard, Smolensky, McClelland, & Hinton, 1986). This view is closer to the underlying brain mechanisms of concept processing than the other four views. In this view, concept is not just a structure embedded in the connection strengths between units; it is also the dynamic process of the network. Concepts are no longer binary: an instance can belong to a concept to some degree, and an instance can belong to different concepts in different contexts. Concepts are no longer static: they can be modified dynamically, they are adaptive, and the acquisition process of concepts is naturally accounted for by the learning mechanisms of connectionist networks. The connectionist view has the potential to become the dominant theory of concepts. However, in implementations, the biggest hurdle is that it is hard to build a connectionist system of concepts that can easily scale up.

Basic-Level Concepts

The five views described above are mainly for intra-level concepts. Many concepts are organized hierarchically: higher-level categories subsume lower-level categories, and different levels of different degrees of abstract. Figure 2 shows a hierarchical structure.

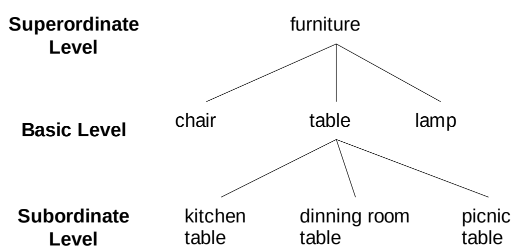

Figure 2. Basic level concepts.

One of the levels in Figure 2 is called basic level, which is cognitively privileged. Basic level concepts have the following properties (Rosch et al., 1976). (1) They maximize information: superordinate level concepts have too little information and subordinate level concepts do not provide much more information. (2) They are neither the most abstract nor the most specific, but intermediate. (3) They are the first to be learned. (4) They are the objects that are naturally named. (5) They are consistent across cultures. (6) The basic level is the highest level in which the instances all share the same parts, overall shape, and associated motor movements. One obvious application of basic level concepts is to design classification systems of medical concepts such that the organization, learning, retrieval, and display of medical knowledge are centered on basic level concepts.

Expertise and Concepts

Another cognitive issue of mental concept representation is the different ways of representing and retrieving concepts by experts and novices. A classic study by Chi et al. (1981) shows that novices used surface features (e.g., physical shapes) to categorize problems while experts used underlying principles (e.g., physics laws) to categorize problems. Another study by Luria (1976) showed people with formal schooling used abstract information to categorize objects. For example, given hammer, log, and saw, these people grouped hammer and saw together because they were both tools. However, people with little formal schooling used practical thinking to categorize objects: they grouped saw and log together because saw was used to cut log. One implication of these studies is that the design of classification systems of medical concepts should consider the different thinking and reasoning styles of expert physicians and less experience medical students and residents.

Conclusions

This paper discussed the differences between medical vocabularies that are designed as external artifacts and the mental concepts that are inside users' heads. It argues that if the controlled vocabularies currently being developed for EMR are to be used by people at all, they should be designed with systematical considerations of the cognitive structures and processes of the users. Without such considerations, the designed vocabularies may not be usable by people, although they may or may be appropriate for machine processing.

This paper described five different

views of mental concept representations. They are mainly for the representation of singular concepts. Although controlled medical vocabularies currently being developed cover simple singular concepts to compound concepts to full range of medical knowledge, the cognitive theories still have values in the design of complex vocabularies. Finally, other cognitive issues such as basic-level concepts and expertise were also introduced. It is argued that the properties of basic-level concepts and the expert-novice differences in concept representations should be incorporated to the design of controlled medical vocabularies.

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